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COMPOSITE MAPPING EXPERIENCES IN AIRBORNE GAMMA SPECTROMETRY

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During an international intercomparison exercise of airborne gamma spectrometry held in Switzerland 2007 teams from Germany, France and Switzerland were proving their capabilities. One of the tasks was the composite mapping of an area around Basel. Each team was mainly covering the part of its own country at its own flying procedures. They delivered the evaluated data in a data format agreed in advance. The quantities to be delivered were also defined in advance. Nevertheless, during the process to put the data together a few questions raised: Which dose rate was meant? Had the dose rate to be delivered with or without cosmic contribution? Activity per dry or wet mass? Which coordinate system was used? Finally, the data could be put together in one map. For working procedures in case of an emergency, quantities of interest and exchange data format have to be defined in advance. But the procedures have also to be proved regularly.

INTRODUCTION

Airborne gamma spectrometry (AGS) was first used in exploration geophysics and geological mapping. After the Tchernobyl accident in 1986 AGS became also an emergency tool for a fast mapping of contaminations. In Switzerland AGS started in 1986 with a geological mapping project in the Swiss Alps. Within this project the methodology for calibration and data processing was developed at the Institute of Geophysics at ETH Zürich[1]. In 1989 the first time the environs of the Swiss nuclear installations were measured. In 1994 AGS was integrated into the Swiss radiological emergency organisation. In the late 1990s the project 'European Coordination of Environmental Airborne Gamma Ray Spectrometry (ECEAGS)' was started which brought together all the AGS teams in Europe. In the follow-up project 'European Calibration and Coordination of Mobile and Airborne Gamma Spectrometry (ECCOMAGS)' a huge common exercise was held in Dumfries and Galloway (Scotland) in summer 2002[2]. Since then, further collaboration between European teams was established on a bilateral base.

In AGS usually large sodium iodide (NaI) detectors are used to achieve a high sensitivity under normal conditions. In areas with high contamination of many nuclides semiconductor detectors can be very useful because of their better energy resolution and their lower efficiency (no saturation). With NaI detectors the sampling time is usually 1 s. Together with the spectra the coordinates of the measurement point, air temperature, air pressure and height above ground are stored. Because of the low counts in a 1-s spectra the so-called windows method (e.g. IAEA[3]) is often used for data processing. There the collected spectral data are corrected for background radiation (aircraft, equipment, cosmic), scattering and changing flight altitude above ground. The net count rates are converted to activities per mass or area using calibration factors, which are determined by comparison of ground and airborne measurements[1].

The uncertainty of the calculated activities depends on the signal-to-noise ratio, changing flight altitude, uniformity of ground soil and cover, ground moisture and vegetation. Additionally, the estimation of ^{238}U activities is strongly influenced by the radioactive noble gas radon and its daughter nuclides in the atmosphere. Their contribution to the measured spectra leads usually to an overestimation of the ^{238}U activities in the ground soil. The influence is minor at lower flight altitudes because of the higher contribution of the ground. Common uncertainties for ^{40}K and ^{232}Th activities are ~20 %, for ^{137}Cs ~50 %.

The data processing and mapping can already be done during the flight[4]. Figure 1 shows a schematic view of the Swiss measurement equipment.

AGS EXERCISE ARM 2007

In 2007 a common AGS exercise with teams from France (CEA), Germany (BfS) and Switzerland (NEOC) was held in north-western Switzerland. There were three tasks set for the exercise: intercalibration of the equipment in the environs of the nuclear power plants Gösgen and Mühleberg; test of the capabilities for searches of orphan sources in a cargo railway area and the composite mapping in an area around the city Basel covering parts of the three countries involved.

In advance to the exercise the quantities and units which the teams would have to deliver were determined (Table 1). Additionally to the given radionuclides the ambient dose equivalent rate $dH^*(10)/dt$ 1 m above the ground should be delivered. The dose rate

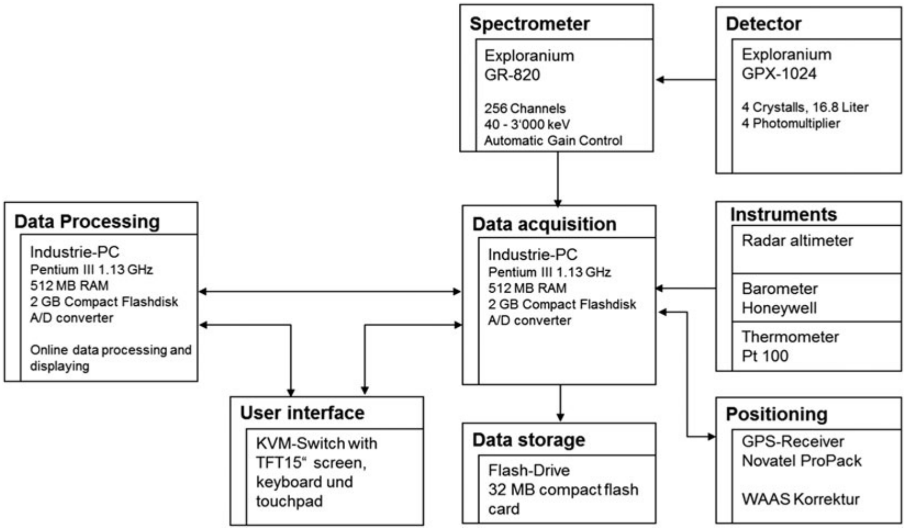

Figure 1. Schematic view of the Swiss measurement equipment.

Table 1. Quantities and units used in the exercise ARM07.

Nuclide	Distribution	Relaxation mass depth (g cm^2)	Unit
^{40}K	Uniform	—	Bq kg^{-1}
$^{214}Bi/^{238}U$	Uniform	—	Bq kg^{-1}
$^{208}Tl/^{232}Th$	Uniform	—	Bq kg^{-1}
^{137}Cs	Surface contamination	0	Bq m^{-2}

should be delivered with and without the cosmic dose rate contribution. Further on the uncertainty for each quantity should be stated.

For the data exchange the European Radiometrics and Spectrometry (ERS) data exchange format version 1.0 developed under the ECCOMAGS project[5] should be used. The coordinates of the measurement points should be stated in the World Geodetic System 1984 (WGS84) or in the local projection Swiss National Grid. Raw and processed data should be delivered in separate files.

For an AGS exercise with several teams with helicopters, logistics play an important role. The military airfield in Dübendorf was the base for the exercise and provided the necessary shelter for the aircrafts. All the measurements started from Dübendorf. During the measurement surveys the aircrafts were partly refilled at other airfields close to the measurement area.

In the following, only the last task is discussed. The results of the other tasks can be found in Bucher *et al.*[6].

COMPOSITE MAPPING

For the composite mapping the existing data processing and mapping software of the Swiss team was expanded. The own raw data file is processed and then stored in a buffer file used for gridding and mapping. With the expansion of the software ERS data files can also be added to a survey. The ERS data are parsed, the coordinates—if necessary—transformed to the chosen mapping projection and then the data are also stored in the buffer file. So a common gridding and mapping of the values became possible.

For the composite mapping each team decided themselves how it want to cover the given measurement area. The line spacing was defined to 250 m. In Figure 2 the measurement flight lines of the three AGS teams are shown. At the area borders some overlap exists. Each team chose its own usual flight altitude and speed to which its calibration is best adapted. The Swiss team is usually flying at 100 m above the ground at 100 km h^{-1}. More detailed information can be found in Bucher *et al.*[6].

Each team measured its part of the area, processed the data and delivered the results in the given format to the Swiss team. The Swiss team was in the lead to produce the composite map. It was found that the delivered data didn't correspond completely to the given ERS data format: different delimiters were used; the symbol '<' was introduced for values below the detection limit; and no date and time were stated in the data.

Activities of radionuclides were delivered partly as activity per dry mass and partly as activity per wet mass. Instead of the ambient dose equivalent rate (DHSR identifier in ERS data format) the absorbed dose rate in air (DAR identifier) was reported. In the

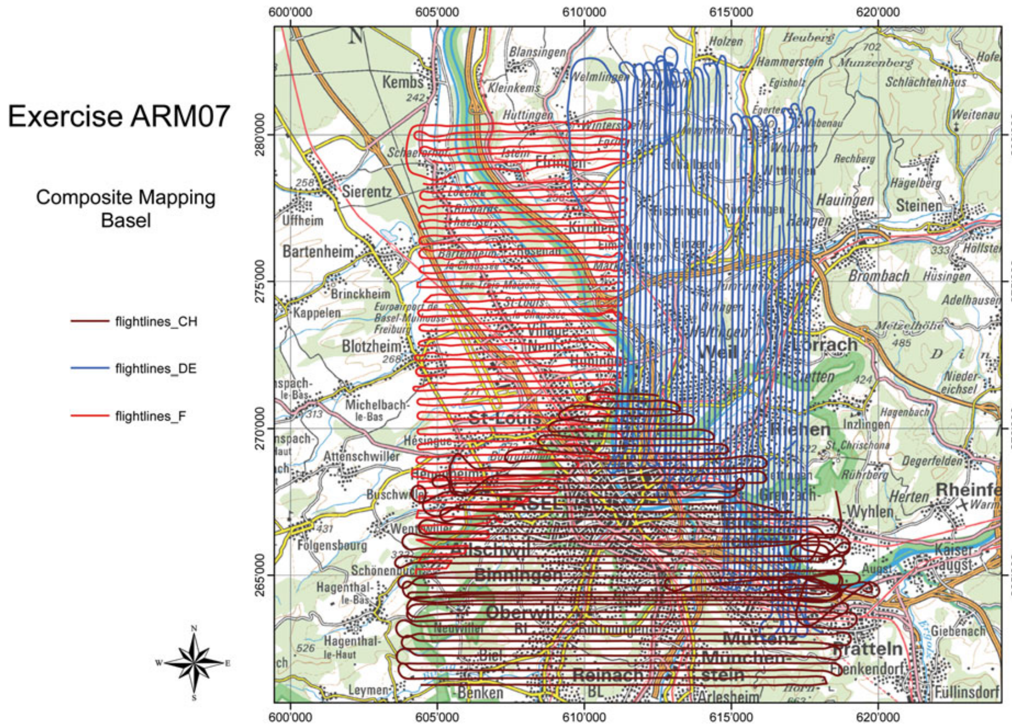

Figure 2. Measurement flight lines of the three AGS teams (Reproduced by permission of swisstopo (BA14019)).

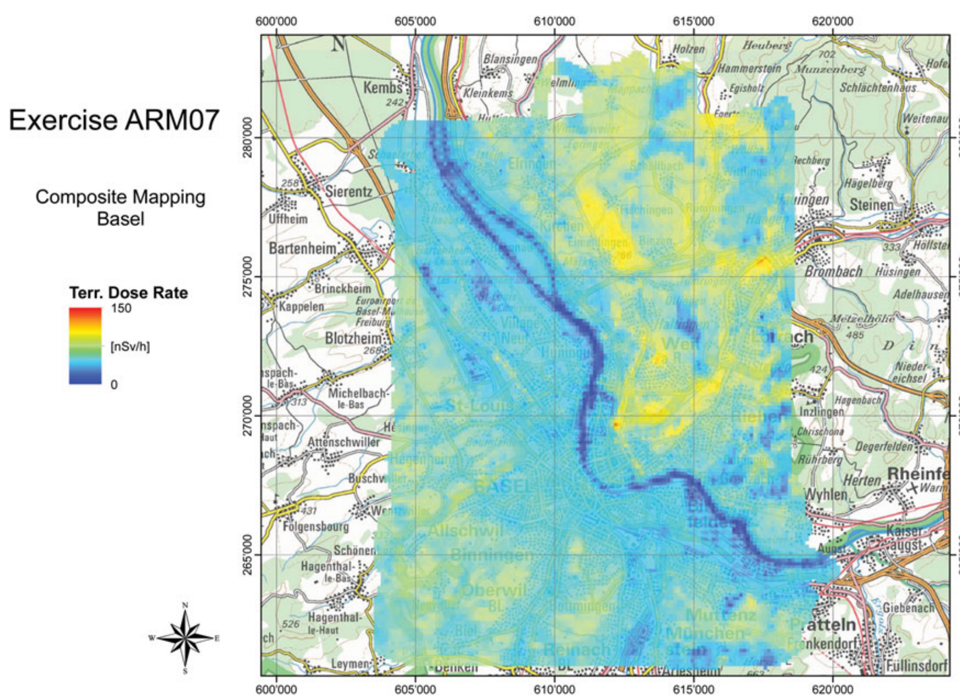

Figure 3. Map of the terrestrial contribution to the ambient dose equivalent rate (Reproduced by permission of swisstopo (BA14019)).

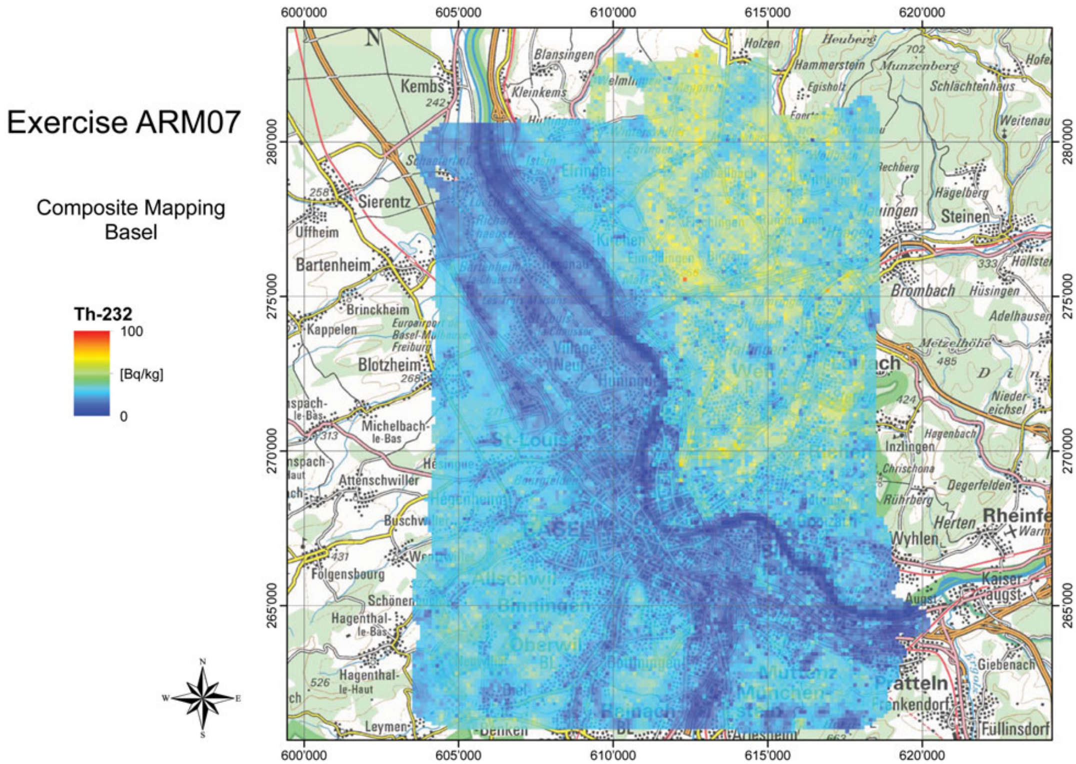

Figure 4. Activity map of the radionuclide ^{232}Th (Reproduced by permission of swisstopo (BA14019)).

delivered data no uncertainties for any quantity were given.

For a fast production of a composite map some workarounds for the problems mentioned above had to be found. So the values where the symbol ‘$<$’ was used were set to ‘no value’. All values with the unit activity per wet mass were converted to activity per dry mass using a conversion factor of 1.25. This factor was estimated assuming a soil density of 800 kg m^{-3} and 20 % of the soil volume filled with water. The given absorbed dose rate in air was converted to ambient dose equivalent rate using the ISO 4037-3[7] conversion factor for the radiation quality S-Cs of 1.2 nSv h^{-1} per nGy h^{-1}.

With these workarounds maps for the terrestrial contribution of the ambient dose equivalent rate (Figure 3) and the activities of the radionuclides ^{40}K, ^{238}U, ^{232}Th (Figure 4) and ^{137}Cs could be produced.

In the maps the lower values above the river Rhine can be clearly seen. There are no steps between the areas measured by the different teams.

CONCLUSIONS

With a few workarounds the delivered data of the three teams could be put together to common composite maps. The workarounds consumed some time, but the maps could be created within a few hours after the data were delivered from all teams.

The exercise showed that a clear definition of quantities and units is needed. Standardisation of quantities and units based on the needs of emergency authorities would be very helpful. Uncertainties of the measured values must be reported. They are needed for the interpretation of the data. But it is still not solved how they could be integrated in mapping.

A common exchange data format as the used common international ERS data format is very important to exchange the data between international experts and to compose quickly and accurately the data in the case of a nuclear emergency.

There must be an agreement on the data format between the measurement teams and the format has to be implemented properly. The quantities within the data format must be clearly defined, e.g. activity per dry mass and activity per wet mass are both reported with the same unit, but there is a difference in its meaning.

There should be no cut-off values. Although negative activities do not make sense in a physical point of view, they are very important from a statistical point of view. In the case of a cut-off the mean value is getting higher than it is in real.

There are many possibilities to make mistakes. So periodical training in real exercises is needed to verify the data formats, the implementation and the procedures for data exchange, processing and mapping.

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